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Influence of lighting conditions on the results of photoelectric measurements of semiconducting detectors *

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The influence of illumination conditions of detectors upon their photoelectric characteristics has been investigated both experimentally and theoretically. It has been shown that under some experimental circumstances the plots of relative photoresponse vs wavelength of nonlinear detectors can be falsified by the spectral characteristic of light source (spectral radiant intensity).

The dependence of spectral irradiance E_ω upon photosignal frequency exhibits nonlinearity connected with excess carrier generation-recombination conditions in semiconductor detectors [1].

When photoresponse is not a linear function of the spectral irradiance, then in a photoresponse spectrogram there may occur an unintentional structure, which is not directly connected with the semiconductor properties but with the spectral characteristic of the measuring set-up. This extra structure may affect the real subtle photoelectric effects, which can be avoided by stabilization of the spectral irradiance falling on the detector. The stabilization is required for both DC and AC methods of photoelectric measurements. A fixed value of the spectral irradiance can be obtained by using a regulated diaphragm built in the light-inlet unit. Spectral irradiance within the area of the detector being measured can be controlled by increasing or decreasing its aperture. When this diaphragm plays the role of an aperture diagram, neither the illuminated detector area nor the spectral irradiance distribution on its area will be changed.

An optical measuring set-up with such a diaphragm should be a two-beam apparatus. Since for stabilization of the spectral irradiance a reference beam has to be employed during the measurements of the detector photosignal. A detector measuring the reference signal (U_0) must have a linear characteristic of photoresponse and constant spectral sensitivity within a wide spectral range. Thermal detectors (e.g., thermocouples) satisfy well these conditions. The diaphragm performance should make constant the reference signal in order to keep spectral irradiance constant. Manual (mechanical) operation does not ensure a good compensation because of high inertia of such a system.

An electronic comparing system enabling the stabilization of spectral irradiance

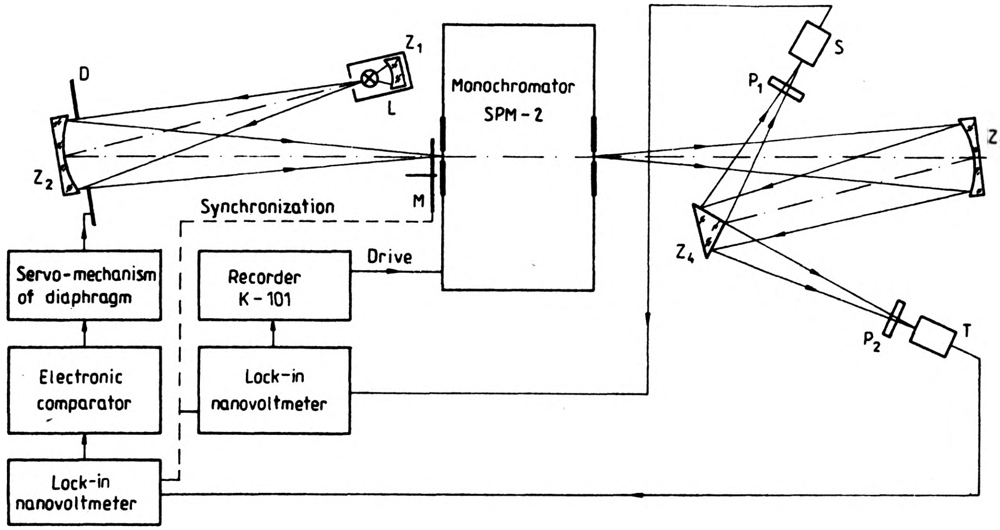

Fig. 1. Block scheme of the photoelectric measurement set-up: D – regulated diaphragm, L – light source, M – chopper, P_1, P_2 – polarizers, S – measured detector, T – thermocouple, Z_i – mirror

within $1^0/_0$ and satisfying the above conditions has been designed and built. It can be useful in measuring systems with both the filament and arc lamps. Its detailed operation principles have been described in [2]. Automatization of the measuring set-up permits a fast and simple performance, being of importance for series measurements. Block scheme of this apparatus is shown in Fig. 1. The presented system makes it possible to measure:

- photoconductivity,
- photovoltaic effect,
- total transmittivity coefficient,
- reflectivity coefficient

in polarized and non-polarized light.

Figure 2 contains a set of theoretical characteristics illustrating the possible way in which the false spectral characteristics of detector sensitivity may be produced. The set of $U_{Ph}/U_0 = f(E_\theta)$ characteristics for some values of λ, where U_{Ph} is the photovoltage of a detector, U_0 is the thermocouple photovoltage, λ is the wavelength, and E_θ is an illuminance (spectral irradiance), is shown in Fig. 2. Since U_0 and U_{Ph} are linear and non-linear functions of E_θ, respectively, the relative sensitivity $\left.\frac{U_{Ph}}{U_0}\right|_{\lambda_i}$ is different for different values of E_θ. If U_{Ph} were a linear function, the $\left.\frac{U_{Ph}}{U_0}\right|_{\lambda_i}$ characteristics would be straight lines parallel to the E_θ axis. The plots in Fig. 2b represent spectral characteristics of a thermocouple photosignal $U_0(\lambda)|_{E_\theta}$, and of relative photosignal $\left.\frac{U_{Ph}}{U_0}(\lambda)\right|_{E_\theta}$ for stabilized (dashed

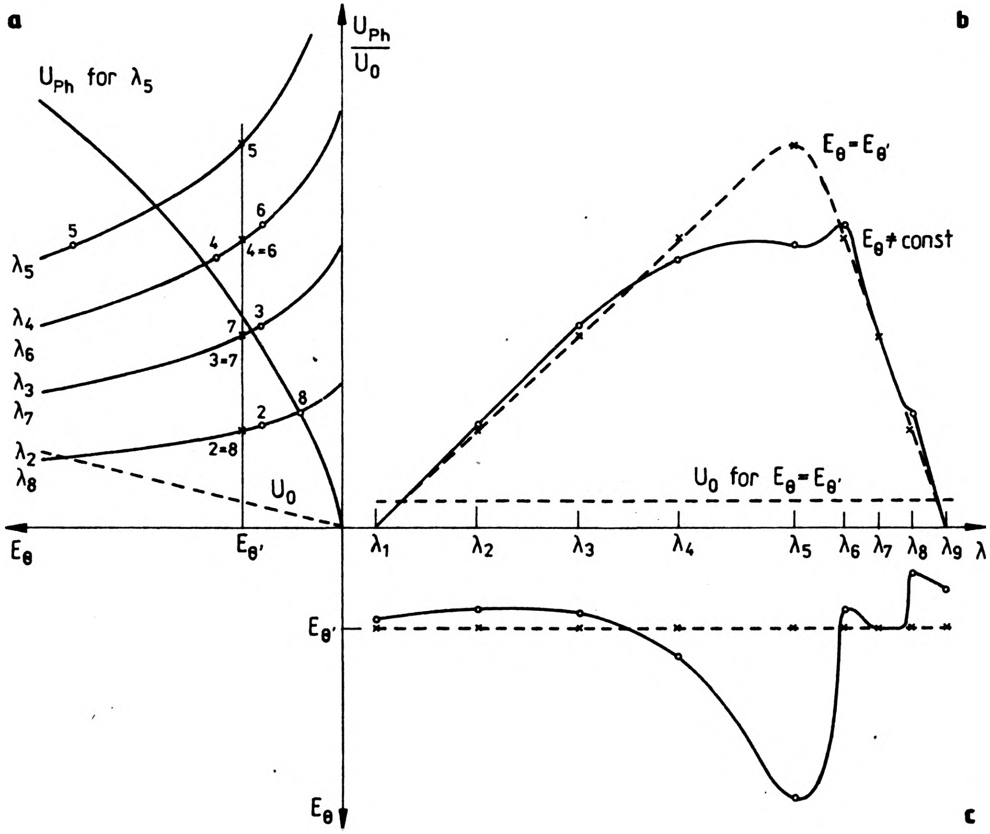

Fig. 2. Set of model characteristics: a — irradiation characteristics of a detector (U_{Ph}), thermocouple (U_0) and relative photosignal (U_{Ph}/U_0), b — spectral photoresponse of a thermocouple (U_0), spectral relative photosignal in cases of stabilized (dashed line) and non-stabilized (solid line) spectral irradiance, c — spectral characteristics of photoresponse for the detector and thermocouple in cases of stabilized (dashed line) and non-stabilized (solid line) spectral irradiance

line) and non-stabilized (solid line) spectral irradiance. Dashed line (real spectrogram) corresponds to the crosses lying on the straight line $E_\theta = \text{const}$, cross-cutting the set of $\left.\frac{U_{Ph}}{U_0}\right|_{\lambda_i}$ characteristics (see Fig. 2a). Solid line (unreal spectrogram) was determined by dots lying on curves belonging to the same set as the previous one. Positions of the dots arise from spectral model distribution of the spectral irradiance $E_\theta = f(\lambda)$, see also solid line in Fig. 2c. Figure 2c illustrates the spectral characteristics of irradiation for detector and thermocouple in cases of non-stabilized (solid line) and stabilized $E_\theta = \text{const}$ (dashed line) spectral irradiance, respectively.

From the above plots it follows that the characteristic structure appearing in a spectrogram of the nonlinear detector photoresponse is solely due to $E_\theta = f(\lambda)$, see Fig. 2c. Spectral characteristics of the measured detectors are not affected by the structure of reference signal U_0, if the spectral irradiance is stabilized.

As an example, the characteristic of photovoltaic semiconducting detector made of $Cd_{0.2}Hg_{0.8}Te$ [4] is presented in Fig. 3. The dashed line denotes the relative photoresponse of measured detector $\left.\frac{U_{\mathrm{Ph}}}{U_0}(\lambda)\right|_{E_\theta}$ for non-stabilized stream. The solid line represents the relative signal from photodetector for the stabilized light stream. The point-dashed line shows the reference signal $U_0(\lambda)|_{E_\theta}$, e.g., a spectral characteristic of the used halogen illuminator. In the measured spectral region the ratio of relative photosignals $\left.\frac{U_{\mathrm{Ph}}}{U_0}(\lambda)\right|_{E_\theta}$ and $\left.\frac{U_{\mathrm{Ph}}}{U_0}\right|_{E_{\theta'}}$ is not constant. It is not difficult to notice a distinct discrepancy between these two signals for stabilized and non-stabilized light stream. If the non-stabilized set-up was used, then compared with the stabilized one the following effects have been observed for the investigated detectors:

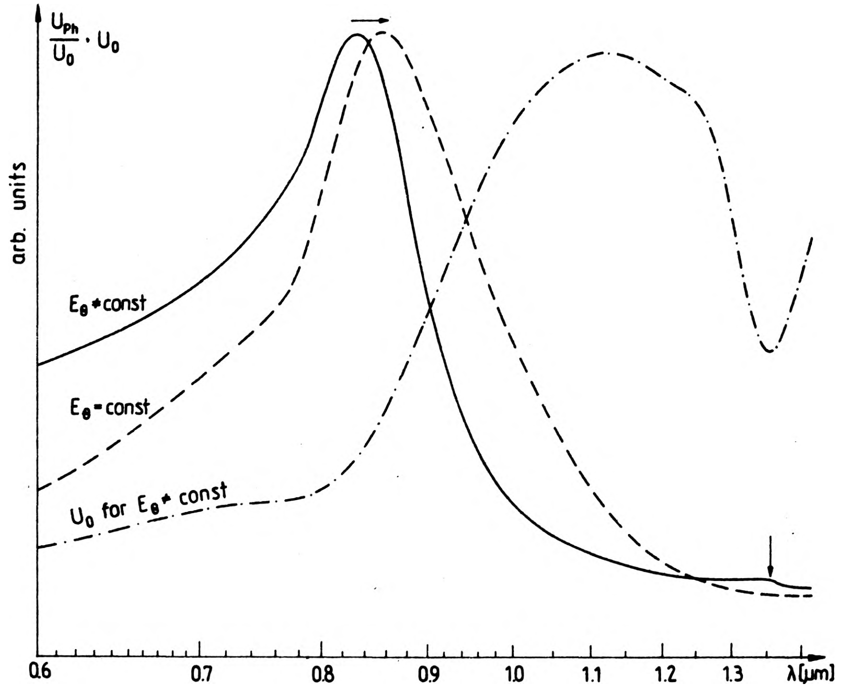

Fig. 3. Spectral dependences of photovoltaic semiconducting detector $Cd_{0.2}Hg_{0.8}Te$ in T = 300 K. Solid line – the relative signal from detector when the spectral irradiance is stabilized; dashed line – the signal when the spectral irradiance is non-stabilized; the point-dashed line – reference signal

i) a shift of the maximum position,

ii) a change of the slopes of the characteristics,

iii) a turning up of some singularities (i.e., in the longwavelength region in Fig. 3).

Some important properties of semiconductor (of which the detector was made) obtained with the help of these characteristics prove the high suitability of the stabilized set-up. For example, the values of longwavelength cut-off (Fig. 3), obtained with the help of both the dashed and solid lines, differ one from other by about 0.2 μm, which is well above the experimental error.

Summing up, it may be concluded that the set-up with the stabilized spectral irradiance makes it possible to avoid blunders and to provide a proper analysis of experimental photoelectric results.

References

[1] SHALIMOVA K. V., *Fizika poluprovodnikov*, (in Russian), Ed. Energiya, Moskva 1976.

[2] GUMIENNY Z., MIROWSKA N., Report No. 135, Institute of Physics, Technical University of Wrocław, Wrocław 1982 (in Polish).

[3] PANKOVE J. I., *Optical Processes in Semiconductors*, Prentice-Hall, Inc., New Jersey 1971 (Polish edition 1974).

[4] BECLA P., ŁAGOWSKI J., GATOS H. C., J. Electrochem. Soc. **129** (1982 a), 1103.

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Влияние условий освещения на результаты фотоэлектрических измерений полупроводниковых детекторов

В работе представлены теоретические и экспериментальные исследования зависимости результатов измерений фотоэффектов от условий освещения поверхности исследуемых детекторов. Доказано, что в определённых условиях измерений спектограмма относительного фотоотклика нелинейных детекторов может быть искажена спектральным распределением интенсивности излучения источника.